AMERICAN INTELLIGENCE.

ORIGINAL COMMUNICATIONS.

On the Digestion of Starch in the Intestinal Canal. By JOHN C. DALTON, Jr., M. D., Professor of Physiology and Microscopic Anatomy in the College of Physicians and Surgeons, New York.

In the *American Journal of the Medical Sciences* for October, 1854, in an article on the *Gastric Juice and its Office on Digestion*, I stated, as the result of a considerable number of experiments, that starchy substances were not digested in the stomach. This statement was in accordance with the opinion of Bernard, but in opposition to that of Lehmann, who asserted, partly on his own authority and partly on that of Jacubowitsch and Bidder and Schmidt, that after an animal, with gastric fistula, had been fed with starch, glucose could be detected in the fluids drawn from the stomach. Lehmann, however, in his third edition, retracts this opinion and embraces the opposite one. "Bidder and Schmidt,"[1] he says, "under whose superintendence the experiments of Jacubowitsch were instituted, have convinced themselves, by later experiments, that the saliva loses its action on boiled starch in the stomach of the living animal. * * * We are, consequently, led, by the earlier observations of Bernard, as well as by the more recent investigations of Bidder and Schmidt, to the conclusion that notwithstanding its energetic action on starch, and notwithstanding its abundant supply, the saliva takes no very important part in the digestion of the amylacea." So far as regards the lower animals, therefore, it seems to be quite generally acknowledged that starch is not converted into glucose in the cavity of the stomach.

In a pamphlet recently published by Dr. Francis G. Smith,[2] of the Medical Department of Pennsylvania College, some very interesting experiments are detailed which were performed by the author on Dr. Beaumont's old patient, Alexis St. Martin, during his recent visit to this section of the country. Their results lead Dr. Smith to the belief that my own observations, in this respect, as well as those of Bernard, were erroneous, or at least not applicable to the human subject; and he concludes that "starchy materials are digested in the human stomach; that human gastric juice does not prevent the conversion of starch into grape sugar, and that this conversion may take place in the stomach, independently of the action of the saliva."

The two experiments upon which these conclusions were based were the following, in which the "amylaceous materials" were "represented by wheaten bread."

"*Experiment* 11. On the 6th of May, a portion of wheaten bread was given to St. Martin while fasting, which he masticated deliberately and swallowed. In two hours and a half afterward a portion of the contents of the stomach was removed for examination. The reaction of this fluid was acid, and the microscopic appearances have been detailed already. Suffice it to say, that, in addition to epithelial and mucous cells, starch granules, some whole, some broken, were distinctly recognizable.

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[1] Physiological Chemistry, English translation. Philad. edit., vol. i. pp. 434–5, 1855.

[2] Experiments upon Digestion. Philad., 1856.

"After allowing the fluid to stand until it had settled, a portion of the supernatant fluid was tested with iodide of potassium and nitric acid with the effect of manifesting decided evidence of the presence of starch by the production of the characteristic blue colour. The same reaction was produced with the tincture of iodine.

"Another portion of the same fluid was subjected to Trommer's test (solution of sulphate of copper and liquor potassæ); the result showed the brick-dust red precipitate from a reduction of the oxide of copper in very considerable quantity." (The above fluid was also filtered through animal charcoal, and afterwards acted in the same way with Trommer's test.)

"*Experiment* 12. In order to ascertain, if possible, what effect the saliva might have had in producing the glycogenic change in the bread masticated, a portion of bread moistened with water was introduced through the fistulous orifice, and St. Martin was requested to swallow as little saliva as possible, which, as he used tobacco, he had little difficulty in complying with. In an hour and a half afterwards, the contents of the stomach were withdrawn. The same acid reaction was manifest; the same microscopic appearances, and the same solution of the materials were present, although not to the same degree as when the bread was masticated.

"The fluid was carried through the same tests with a like result, viz: faint evidences of starch and decided evidences of glucose."

I cannot think that the above experiments really indicate that the amylaceous matters were digested in the stomach. On the contrary, it is extremely probable, to say the least, that the glucose which was detected in the gastric fluids, was not formed during the process of digestion, but *existed beforehand in the bread used as food.* When I first commenced to investigate the subject of the digestion of starch, and the place of its conversion into sugar, the plan adopted was to feed the animals (rabbits and dogs) with bread or biscuit, kill them after a short time, and then examine the contents of the stomach and intestine. It was very soon found, however, that this method would not answer the purpose—for the reason that nearly every kind of bread and biscuit contains a certain quantity of glucose; and when this substance was found in the fluids of the alimentary canal after the death of the animal, it was impossible to determine whether it had been produced by digestion or taken in with the food. The only sure mode of experimenting is to feed the animal with a recently prepared emulsion of starch, mixed with meat, the mixture being tested beforehand to make sure that it contains no sugar. This was the mode finally adopted; and it led to perfectly satisfactory results.

I have recently examined fifteen different specimens of wheaten bread, procured at random from ten different establishments, and found glucose to be present, in larger or smaller quantity, in all of them. In twelve specimens the glucose was sufficiently abundant to reduce the oxide of copper in Trommer's test promptly and copiously; in the remaining three instances, the traces of glucose were slight, though distinctly present. The bread is simply rubbed up with a little distilled water, allowed to soak a few minutes, filtered, and the filtrate tested in the usual manner for the presence of sugar. In some kinds of crackers, or hard biscuit, there is also a considerable quantity of sugar; in others it is not present. Sometimes one biscuit will furnish evidences of the presence of sugar, while another, taken from the same lot, will fail to do so.

Most of the glucose which is found in ordinary bread is derived directly from the flour, in which it exists in considerable quantity. During the process of fermentation, or "rising," a part of it is converted into alcohol and carbonic acid, but a certain portion escapes decomposition, and remains unaltered. It is probable, also, that some of the starch of the flour becomes converted into glucose, either during fermentation, or in the process of baking. Whenever milk is used as an ingredient of bread or biscuit, it supplies, of course, an additional quantity of sugar. It is certain, at all events, that bread is quite unfit to be used as the material for experiments on the digestion of starchy substances.

The method adopted in my experiments on dogs, as already mentioned, was to administer to the animal, after a twelve or twenty-four hours' fast, boiled starch mixed with meat. The experiments were first performed on animals with gastric fistulæ, the fluids being withdrawn from the stomach at various intervals after the meal. It was found that in the fluids so extracted starch was easily recognized, by its reaction with iodine, ten, fifteen, and thirty minutes after the ingestion of the food. In forty-five minutes it had diminished in quantity, and in an hour had almost invariably disappeared; but no glucose was present at any time. It was thus ascertained that the starch disappeared from the stomach without undergoing any appreciable conversion into sugar; but the manner and place of its final digestion was still uncertain. A second set of experiments were then performed on healthy animals, which were fed in the same way, then killed, and the contents of the alimentary canal examined. In this way it was definitely ascertained that during digestion starchy matters pass unchanged from the stomach into the duodenum, and that they there meet with the mixed intestinal fluids, by which they are at once converted into glucose. The intestinal fluids taken from the duodenum of a recently killed dog exert this transforming action on starch with equal promptitude outside the body, if the two substances be mixed in a test-tube and kept at the temperature of 100° Fahr. The following experiment, which I have often repeated, shows that the same conversion occurs in ordinary digestion: If a dog be fed with a mixture of meat and boiled starch, and killed a short time afterwards, the stomach contains starch, but no glucose; while in the duodenum there is abundance of glucose, but little or even no starch. The experimenter may, however, fail to discover sugar in the intestine under these circumstances, if the examination be too long delayed; for it is remarkable how rapidly starchy substances, if in a fluid form, and disintegrated by boiling, are disposed of in digestion. If the animal be fed, as above, with boiled starch and meat, while much of the meat remains in the stomach for eight, nine, or ten hours, the starch immediately begins to pass out of it into the intestine, where it is at once converted into glucose, and then as rapidly absorbed. The whole of the starch may be converted into glucose and absorbed in an hour's time. I have even found, at the end of three-quarters of an hour, that all trace of both starch and sugar had disappeared from both stomach and intestine. The promptitude with which this passage of starch into the intestine takes place, as well as its subsequent digestion and absorption, varies to some extent in different animals, according to the activity of the digestive apparatus; but it is always a comparatively rapid process.

Some caution requires to be used in examining the gastric and intestinal fluids for sugar, owing to the peculiar property of gastric juice in modifying the action of Trommer's test on a solution of glucose. If much gastric juice be present on adding the sulphate of copper and potassa, a fine purple colour is produced instead of the ordinary blue tinge; on boiling, the colour changes to yellow, but no deposit of copper takes place. If the quantity of sugar be very small, and only a little sulphate of copper used in the test, no change of colour may occur on boiling, and the mixture may remain purple. This singular property was first described in an article, already alluded to, published in the number of this Journal for October, 1854. At that time I was unable to ascertain on what ingredient of the gastric fluids this peculiar action depended. Subsequently, however, the same thing was noticed by M. Longet, of Paris, and described by him in the *Gazette Hebdomadaire* for April 9, 1855.[1] He ascribes this modifying influence on Trommer's test to the presence, in the gastric fluids, of digested albuminose. I have since found that this opinion is correct. Pure, colourless gastric juice, taken from the stomach of the fasting animal by irritation with a metallic catheter, does not interfere with the usual action of Trommer's test. But if it be artificially digested for some hours with finely chopped meat, at the temperature of 100° Fahr., and then filtered, it will be found to have acquired the property in a marked degree. As the fluids of the stomach, while digestion of meat is going on, always contain more or less albuminose in solution, they will modify accordingly the action of Trommer's test. If care be taken, however, this need not produce any great uncertainty in its use; for the albuminose acts only to a limited extent, and in proportion to its relative quantity. In other words, a certain quantity of albuminose will only prevent the reduction of a certain quantity of copper. Thus, if we have a specimen of gastric juice containing both albuminose and grape sugar in solution, if we add a small quantity of sulphate of copper (one drop of the solution, for example, to one drachm of gastric juice), on making the mixture alkaline by the addition of potass, it takes a purple colour, and no deposit occurs on boiling; but if we add a larger quantity of copper (four drops to the drachm), the colour of the mixture is blue, and the copper is partly precipitated on boiling. As a general thing, whenever sufficient sulphate of copper is added to make the mixture blue instead of purple, some of it is thrown down on boiling if glucose be present.

Another precaution is necessary in the examination of the animal fluids for starch. Since both the gastric and intestinal fluids interfere in a marked degree with the mutual reaction of starch and iodine, it is necessary, in searching for starch, to employ the iodine in excess; since a small quantity would be altogether held in check by the organic matters, and would fail to detect the starch which might be present.

The Patella torn away by a Circular Saw, with other Serious Injuries; Recovery. By WM. J. ALEXANDER, M. D., of Salem, Va.

On the 6th day of April, 1855, I was called to visit Mr. John Eller, a Dunkard preacher, aged 60 years, and of a bilious temperament, residing five miles distant in the country, who after having shut the water from a seventeen foot wheel, by which the saw was propelled, turned around quickly and in attempting to remove a piece of scantling which lay upon the carriage, the end came in contact with the saw, and Mr. Eller was instantly drawn towards it; falling on the left side of the saw, he received four severe wounds before it ceased its motion. When I arrived and examined my patient, I found the pulse at the wrist scarcely perceptible under the fingers; a cold perspiration pervaded the whole system. After the system had fully reacted from large and repeated draughts of brandy which had been given, I proceeded to examine the injuries which he had sustained, and found that

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[1] *Nouvelles Recherches relatives à l'Action du Suc gastrique sur les Substances Albuminoïdes.*